OPTIMUM TEMPLATE SELECTION AT MARGINAL FIELD

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Petroleum Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
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Approved by,

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(Dr Sonny Irawan)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JULY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I was responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained here have not been undertaken or done by unspecified sources or person.

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ANANTRAM A/L GANGARAJ

ABSTRACT

Template selection is significant in saving time and money in the oil and gas industry. The problem of selecting an optimum template is mainly the type of vessel to be deployed for template operations and also the operational risk present. The objective of this project is to determine the suitable type of vessel to transport and install the suitable type of template. Other than that it is important to calculate the time and cost in relation to the template selection. Weather conditions of the open sea needs to be considered as well. Marine operations at South China Sea are companied along with the presence of typhoon, giant waves or even monsoon wind and these risks besides other common hazards may jeopardize the overall project by wasting precious time and cost. Literature studies have showed that two common types of template utilized in marginal fields are Integrated Template Structure (ITS) and Stacked Template Structure (STS). These templates are different in mass, design and installation method. In this project, several analyses have been done to compare both types of templates mentioned. These analyses shown in methodology chapter emphasize the usage of mechanical knowledge in particular vessel dynamics formula and also petroleum economics during time and cost calculations. First, template selection based on type of vessel is done by calculating and comparing the heave period of each vessel in relation to the type of template structure. It is known that the lower this heave response, the worse the performance of the vessel in waves. For this project, it is found that the Semi-Submersible Crane Vessel (SSCV) to be the most stable vessel to be operated at South China Sea boasting a heave period value of 19.3 seconds therefore recommending SSCV preferable for ITS and monohull vessel suitable for STS. Once vessel selection is complete, the next step is to calculate the transportation and installation time and consequently cost. For this project purpose, the Sepat field is chosen as the marginal field located at South China Sea. Cost calculation is done by multiplying vessel daily rate and vessel total operation time. Vessel transportation time is the product of vessel average speed and the distance from Sepat field to its nearest port which is 130 Km. From literature studies, I've also leart that weather-critical operation is one of the important element in template selection therefore cost calculations considering the weather effect on operations is done by introducing waiting on weather (WOW) factor in the cost calculation formula. The results show that ITS transportation and installation carries a higher cost than STS and more templates also increases installation cost due to the complexity. It is also proven that weather conditions significantly increases cost as well. Next, Hazard identification (HAZID) studies will be conducted. Hazards identified in this project are based on historical information and past experiences of other field operations in South China Sea. Risk rating is determined by the product of severity and probability of occurrence. Results show that the ITS which is heavier than STS consumes more installation time due to its complexity, thus presenting more risks and hazards which needs more mitigation measures. The project concludes STS is better compared to ITS in marginal fields and also future recommendations to improve the project are included.

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ABBREVIATIONS

O&G	Oil and Gas
ITS	Integrated Template Structure
STS	Stacked Template Structure
SSCV	Semi-Submersible Crane Vessel
WOW	Waiting on Weather
HAZID	Hazard identification
PETRONAS	Petroliam Nasional Berhad
ROV	Remotely Operated underwater Vehicle
PSV	Platform Supply Vessel
RSV	ROV support vessel
DSV	Diving support vessel
FSV	Field support vessel
QRA	Quantified Risk Analysis
ALARP	as low as reasonably practicable
HAZOP	Hazard and Operability studies
PHA	Preliminary Hazard Analysis
CDB	casing drilling bit
BHA	bottom hole assembly
OWP	offshore wellhead platform
AWB	Accommodation and Working Barge
CPDO	Competent Person for Diving Operation
FPSO	Floating Production Storage and Offloading
JRA	Job Risk Assessment

NOMENCLATURE

l	: Length, m
w	: Width, m
k	: Stiffness, N/m
ρ	: Density, Kg/m^3
g	: Gravity acceleration, m/s^2
m	: Mass, Kg
t	: Time, s
A_w	: Waterline area, m^2

CHAPTER 1
INTRODUCTION

1.1 Background study

The O&G industry has always been targeting to maximize profit by producing oil at the most economically viable rate especially in marginal field development. Cost effectiveness is achieved by starting hydrocarbon production at the earliest opportunity in order to reach the plateau rate as quickly as possible which leads to recovery of capital outlay. For a conventional multi well offshore development, drilling begins after installing a fixed platform which consumes more time and money. Earlier production can be achieved by pre-drilling the wells through a drilling template previously installed on the sea bed and the wells can be tied back to surface production facilities. A template is defined as a subsea structure on the seabed that provides guidance for drilling or other equipment [1]. It is also the structural framework which mainly consists of well slots that supports other equipment, such as manifolds, risers, wellheads, drilling and completion equipment, and pipeline pull-in and connection equipment. The structure should be able to withstand any loads, such as from thermal expansion of the wellheads and the pipelines. Other functions of template are collection and distribution point for oil production, oil export, gas lift and water production. The template is typically used to group several subsea wells at a single seabed location. Templates may be of a unitized or modular design. Actual templates may combine features of more than one of these types depending on circumstances. Once design and fabrication of the templates completed, these templates are transported to its designated location and installed using specific vessels and equipment depending on the type of templates to be installed and also the weather condition to execute the offshore operation. Since this project is focusing on the operations of Sepat marginal field which is located in the South China Sea, risk and severe open sea conditions present needs to be indicated and analyzed as well. Detailed explanation will be available throughout this project report.

1.2 Sepat Oil Field

Malaysia has 106 marginal oil fields containing 580 million barrels of oil with Petroliam Nasional Berhad (PETRONAS) having plans since the year 2010 to develop 25% of the total marginal oil fields to replenish its oil reserve and generate new revenue streams. A marginal oil field is defined as a field that can produce 30 million barrels of oil or less but with crude oil around $100 per barrel, these marginal fields hold $58 billion worth of oil [2]. For this project we will consider only one particular marginal field for evaluation purpose, Sepat oil field.

Sepat oil field which widely uses ITS is located 130 kilometers from Kuala Terengganu and 80 kilometers from Dulang in the Block PM 313.Sepat started its first production of crude oil on first half of year 2012.The nearest port to mobilize vessels or equipment to the Sepat field is the Kemaman Supply Base located 130 kilometers away [3]. This distance is an important parameter to be used in this project for time and cost calculation. The location for Sepat field is presented in Figure 1.

Figure 1: Sepat field location [3]

1.3 Location environment

The geographical position of the Sepat field and the severe sea conditions of South China Sea affects the offshore operations, resulting lost in time and money. Factors degrading the operational process are:

- Insufficient operating period
- Environmental risk
- Severe sea conditions
- Lack of technology, competence and experience in marginal field development
- Risk of severe weather conditions at open sea
- Transfer and evacuation of personal
- Importance of uninterrupted material and equipment supplies
- Coastal infrastructure and complicated logistic of remote location

Despite many factors listed, this project will scrutinize the more specific environment conditions due to its larger influence on offshore operations. The more specific environmental conditions present in the South China Sea are:

- Monsoon winds
- Waves/Soliton
- Currents
- Typhoons

1.4 Problem statement

As marginal oil field developments enters the mature state, production starts to decrease due to reservoir natural decline and O&G companies usually will try to sustain the production rate from declining by either performing well services intervention, artificial lift, or drilling additional wells. For offshore oil and gas field, drilling new wells is possible only if there is still well slots available on the wellhead platform template but usually space constraint and other difficulties exist preventing the process of adding more well slots. More over methods such as platform extension or casing drilling presents risks as well as having massive additional capital requirements. In order to avoid these future predicaments, it is better to prevent than cure. Prevention is done by analyzing and choosing the suitable type of template structure to be installed at the early stages of the marginal fields. Besides influenced by mass and cost of template structure, the template selection criteria are also influenced by marine operations which are the template transportation time and also the cost to transport and install the template. On the other hand, marine operations are affected by the type of vessel used and also weather conditions at the open sea. Therefore, a suitable template structure and reliable vessel need to be decided to pursue marine operations meanwhile risk analysis is required to minimize risk and hazards present for a safe and cost efficient and time saving operation.

1.5 Objective and Scope of study

The main aim of this project is:

- To determine the most suitable vessel to be used for template operations at the sea.
- To compare and select the optimum template structure which is time and cost saving in marine operations.
- To conduct cost analyses including weather influence on template operations to determine the template structure with lowest operation costs.
- To perform risk analysis regarding the threats and consequences present; risk assessment matrices and mitigation actions are established.

CHAPTER 2
LITERATURE REVIEW

2.1 Past experience

Research from previous case studies indicates several different methods of adding well slots on a template and there are many risk and hazards present during the execution of these methods.

Martin and Walters in 2010 [4] published a paper which states that artificial islands may have a much larger well capacity (200 or more wells) and larger slot separations (15-30ft).This study also say that wells can be assigned initially to slots within a cluster based on optimized drilling parameters such as:

- Drilled footage
- Dog-leg severity and 3-D complexity
- Well anti-collision analysis
- Batch drilling on clusters

Also further improvement of the slot allocations can be done by considering:

- Well sequence required to reach targeted production build-up to plateau rate
- Well pad layout, construction and well hook-up
- Rig quantity, type and capacity
- Reservoir management strategy including numbers of producer and injector wells
- Future well designs and in-fill locations

Stefano De Luca and Enis Aliko in 2009 [5] published a paper on adding an extra slot at the Foukanda field offshore Congo. The problem arises when all of the eight slots on the seabed template have been drilled as can be seen in Figure 2.

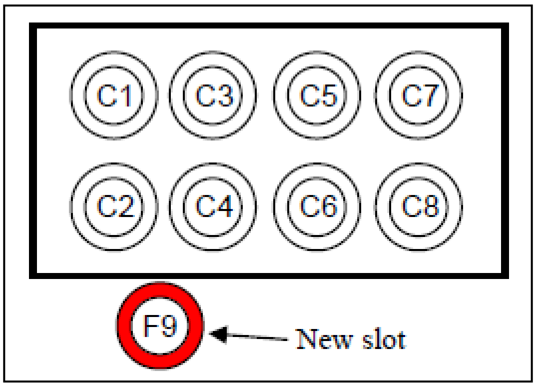

Figure 2: Adding extra slot [5]

The author states that drilling new wells alongside existing wellbores can't be done since most of the existing wells are deviated and this alternative idea requires measures to be taken to avoid collision with the existing wells. The method chosen was to place a "deflector" conductor pipe on the sea bottom and drill the surface section with casing using a casing drilling bit (CDB) from a pre-cut window. Figure 3 shows the schematic of mentioned method.

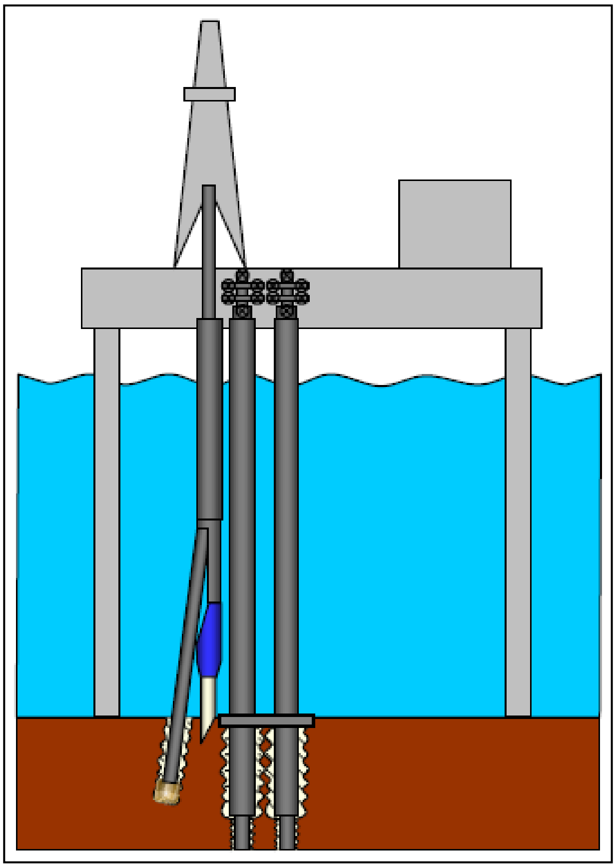

Figure 3: Casing drilling method [5]

The advantage of this method compared to conventional bottom hole assembly (BHA) drilling is that the casing would guide the bit further away from the window, generating less sag, and the casing would already would be in the hole. Using casing drilling with a CDB enabled the drilling of six extra wells from a platform that had no more empty slots on the template but the cost will be significantly higher.

Chandra Irawan and Wahyu Prawira Husen in 2012 [6] published a paper on extending the wellhead platform to add new well slot. Total E&P (TEPI) has implemented offshore wellhead platform (OWP) extension in seven existing platform at Peciko field and Sisi Nubi field around Mahakam area-East Kalimantan, Indonesia.OWP targeted to have additional three or four new slots with ability to accommodate dual splitter wells. Platform top site structure section deck (lower, mezzanine and upper deck) will be modified and also include installation of conductor pipes guide and its protection frame at platform jacket section as can be seen in Figure 4. Platform extension and new slot allocation is shown in Figure 5.

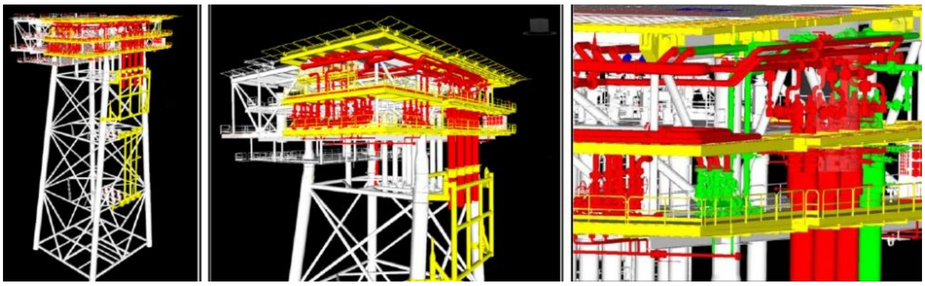

Figure 4: Platform top site modification [6]

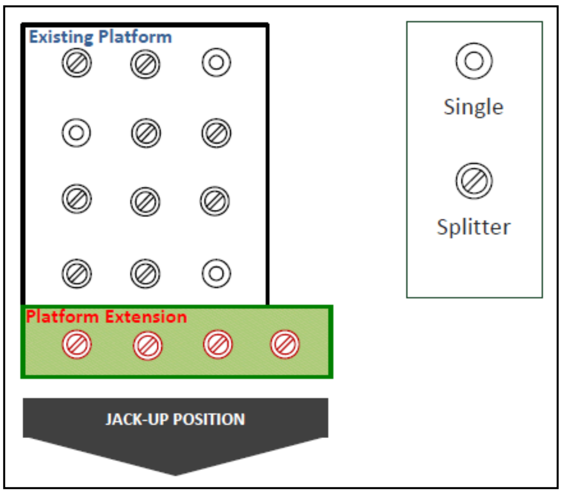

Figure 5: Platform extension and new slot allocation [6]

In OWP there are several risks present, such as:

- Naked flame works: Naked flame job is any activity that can produce fire or sparks such as welding, grinding, and cutting with torch or disk cutter
- Heavy lifting: Heavy lifting is primarily for lifting the platform extension structure into its position usually done using pedestal crane
- Anchoring/De-anchoring: This activity possesses risk because there is possibility of Accommodation and Working Barge (AWB) drifted towards platform and hit the platform which leads to platform damage or even worst to gas leak and explosion. Other risk present is the possibility of AWB anchor hitting the production pipeline lying on the seabed during anchor drop or tensioning
- Saturation/Air diving: Diving operations has major risk of loss of air supply, drifted by current, hit by object under water, animal attack, and decompression sickness. Supervision under company Competent Person for Diving Operation (CPDO) is necessary before project execution
- Working at height: Scaffolding installation, piping works, and structural installation requires working at height

These risks can be avoided if optimum template was selected correctly at beginning stage of template installation.

Another similar study was done by Yi Wang,Menglan Duan,Jinlin Hou,Xu Jia and Xinzhong Li in 2011 [7] on SZ36-1 oil field stating that there are two methods for offshore jacket platform to adding slots;”external adding slots” method and “internal adding slots” method as shown in Figure 6.

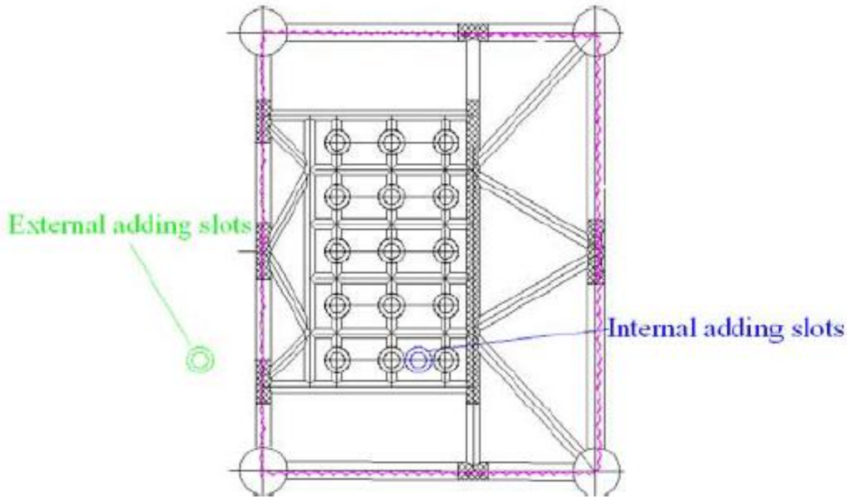

Figure 6: External/Internal adding slots method [7]

This study also stated several factors that must be considered when adding slots to the existing platform:

- The structural characteristic effect of the existing platform
- The number of new slots
- Meeting drilling and completion requirements
- Difficulty of construction and installation

It is learnt that this method adds difficulty of construction and installation and can be avoided if correct type of template was installed during early stages. The addition of new structure on existing platform is shown in Figure 7.

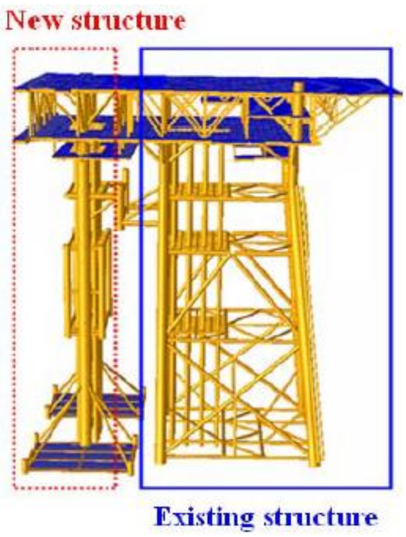

Figure 7: New structure on existing platform [7]

2.2 Template Structure and Operations in Marginal fields

Abdel Ali and Siem Troost in 2013 [8] published a paper about the installation of ITS using SSCV Thialf in deep sea. It is learnt that it is beneficial to use installation vessel with low wave response. The ITS installation was conducted within four phases with the first being Free hanging structure followed by Splash zone, lowering to seabed, and finally structure settling on seabed.

Chris R.Landeck, 1996 [9] published a paper on the application of STS at Seguni field, Indonesia. The design of this template is the stacking of three or four multi-well templates on top of one another at the sea bottom. Each template installed with open clamps with three well slots arranged in a triangular pattern on 15foot centers. The use of ‘’splitter’’ wellheads can double the capacity for wellbores on a single STS meaning the introduction of eight wells. Each template weighed around 100 tonnes. The installation vessels required for the STS installation included a drilling rig, 180ft construction barge with 4 point mooring system, a dive support vessel and a 150ft material barge containing the components of the template. A total of 9.2 rig days needed to complete the four step installation as shown in Figure 8. The first STS started production within eight months of discovery with only four wells. The STS was stable enough to withstand the maximum current induced forces likely to occur.

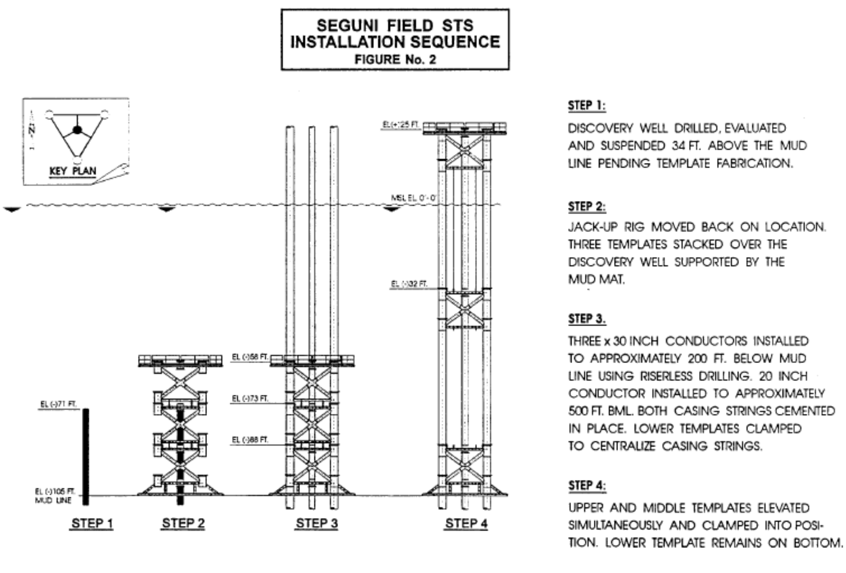

Figure 8: STS installation method [9]

M.Hairi,Afendy, Yusoff,Rahmat, Wibisono in 2010 [10] published a paper about operational safety case study in South China Sea. From this study, standard guidelines called “PETRONAS Guideline for Barges Operating Offshore Malaysia” or PGBOOM is necessary to be followed for installation barges specification. Barges positioning is indicated by three factors:

- The barge direction should be at orientation of current direction to avoid barge drifting away from platform
- Awareness of Floating Production Storage and Offloading (FPSO) anchor patterns to avoid potential collision of barge and FPSO during bad weather
- Vessel service provider and PETRONAS working together to prevent anchor damaging pipelines on seafloor which can be catastrophic

M.M. Abdel Ghany and H.M. EI Ahmady in 1993 [11] published a paper on the procedures of installing drilling template. Drilling templates applications are known to be very beneficial in developing off shore projects since both drilling and construction phase occurs simultaneously. The installation operation sequences are described below:

1. Wellhead conductor inspection and cleaning.
2. Jack-Up Rig positioning.
3. Clamps installation.
4. Template installation.
5. Template grouting and grout allowed curing.
6. Docking pile installation.
7. Sectioning of docking pile guides from the template.
8. Final survey of sea-bed.

Kenneth Aarset, Arunjyoti Sarkar and Daniel Karunakaran in 2011 [12] published a paper about the latest template towing and installation technique invented by Subsea7 company which emphasizes safety, cost-effectiveness and flexibility with reduced requirements to the installation vessel. This submerged towing method is also known as wet tow method. The improvement of wet tow method is the capability of handling massive weighted templates, reliability of complex ROV operations, and operational abilities in harsh environmental conditions. Besides that it also eliminates offshore lifting operation. The method for tow and installation is listed below and illustrated in Figure 9:

1. Wet-store operation
2. Pick up and Hang-off of structure
3. Tow to field
4. Template installation
5. Tow and installation analysis

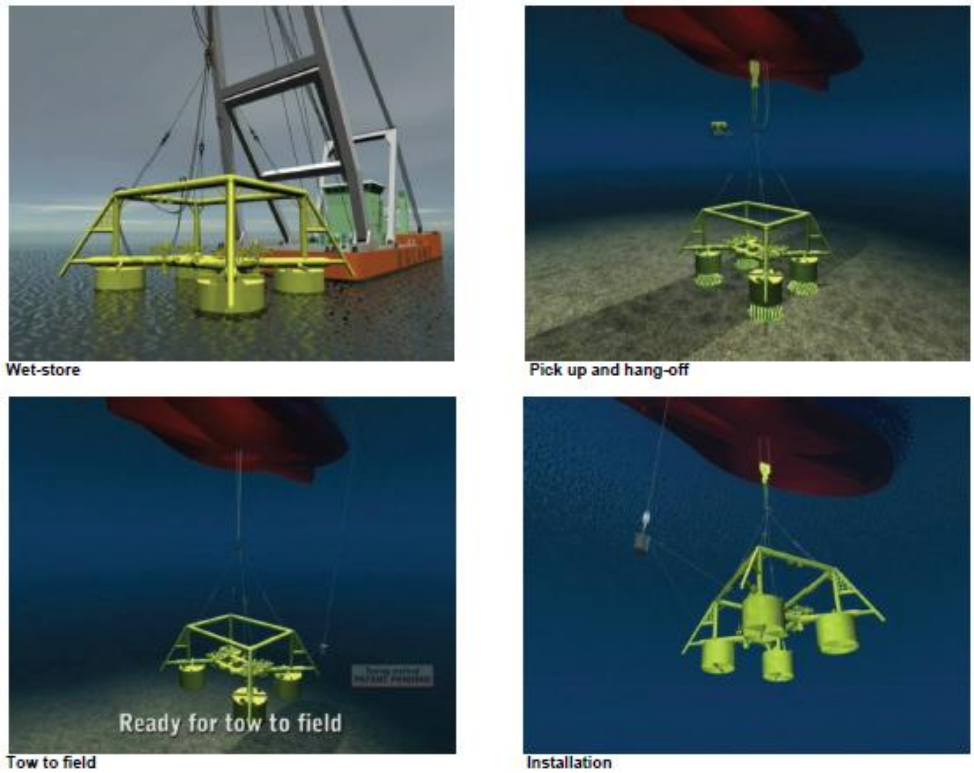

Figure 9: Wet-tow operation method [12]

This method has been applied in Tyrihans project during the installation of four subsea templates using a small monohull construction vessel. The following are the conclusions and lessons learnt:

- No manual handling of heavy rigging offshore
- All heavy lifts were performed inshore in sheltered waters
- Extremely limited exposure to personnel
- Cost-effective solution
- Ensure availability of vessels
- Limited use of sophisticated cranes software/technical

2.3 Operational risk in the South China Sea

Tore Jacobsen in 2014 [13] has produced a paper regarding the installation of subsea structures using construction vessels in harsh environments. The important lesson highlighted from this paper is that marine operations usually delayed due to environmental conditions exceeding prescribed operational levels leading to a possible increase in the operation time. Marine operations that must be done without break are called weather-critical operations. Weather-critical operations are one of the criterions of template selection. For example, heavier template operations usually conducted during calm weather conditions to avoid risks meanwhile lightweight templates have no problem to pursue installation in harsh weather conditions. A template installation done by a crane vessel has usually an operation reference period of 12 hours.

Xu Liangbin, Jiang Shiquan, and Zhou Jianliang in 2013 [14] produced a paper on the challenges and solutions of the South China Sea. From this paper, it is known that operation in South China Sea is risky due to the presence of typhoon, tropical cyclone and soliton. In mathematics and physics, a soliton is a self-reinforcing solitary wave (a wave packet or pulse) that maintains its shape while it travels at constant speed. Soliton causes vessels and barges to drift out of operational parameter because soliton generates two waves with opposite directions. This paper also states that vessel operations are safer at low wave resonance energy effect, therefore emphasizing the importance of having a greater heave period value. Figure 10 shows the statistic results of local typhoon occurrence in recent 30 years in South China Sea. It shows there are 71 typhoons in sum and an average of 2.4 local typhoons each year.

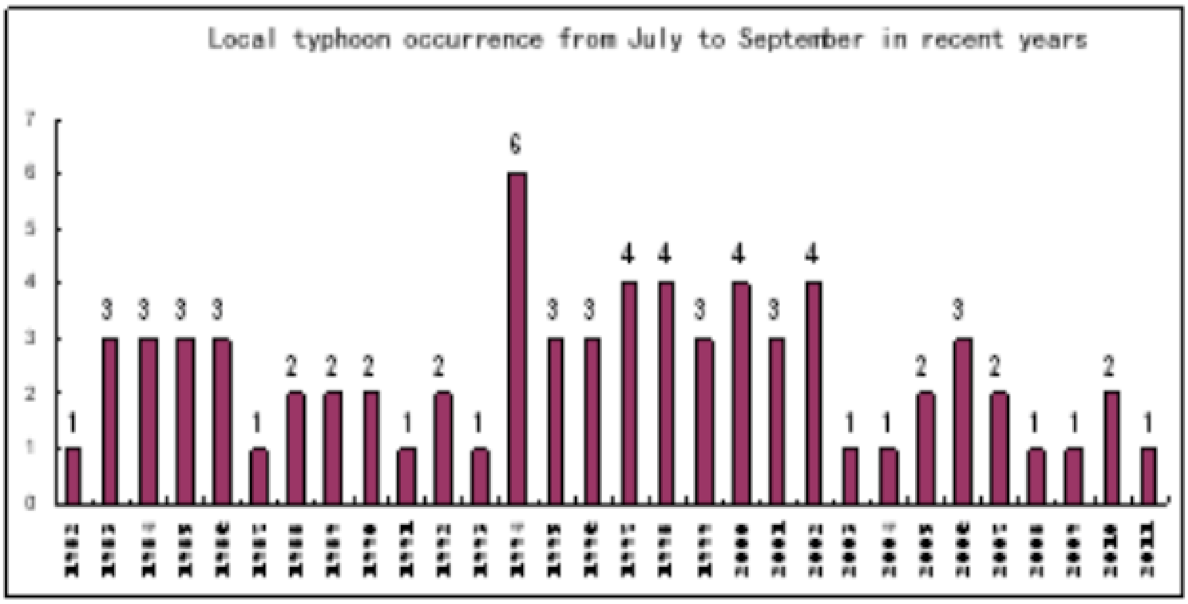

Figure 10: Statistic of typhoon occurrence in South China Sea [14]

2.4 Well Template

There are several types of template available in the market and can be manufactured according to the required specifications. Definition and information of general type of templates are described next [15].

2.4.1 Multiwell/Manifold template or drilling and production template

A multiwell/manifold template (also often referred to as a drilling and production template) is a template with multiple wells drilled and completed through it, and incorporating a manifold system for gathering of produced fluids and/or distribution of injected fluids, as well as a production riser support (Refer Figure 11). This type of template also includes connection point for tie-in of flow lines or production risers to/from the manifold to the host facility.

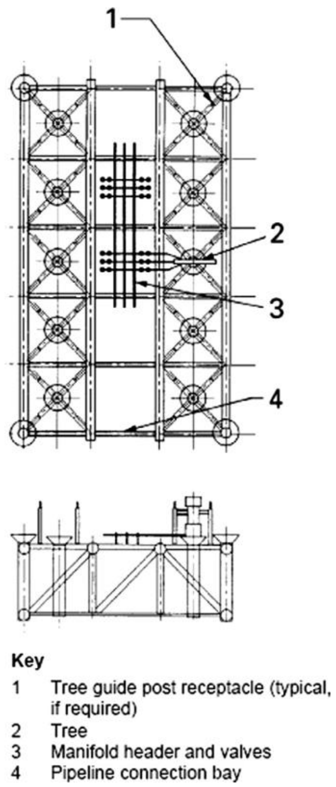

Figure 11: Manifold template [15]

2.4.2 Manifold template/Center

A manifold template is a template used to support a centrally located manifold for gathering produced fluids and/or distribution of injected fluids (Refer Figure 11). Wells would not be drilled through such a template, but may be located near it or in the vicinity of the template. In this arrangement, individual satellite wells are clustered around the manifold and tied back to the manifold using either flexible or rigid pipe. This type of template also includes connection point for tie-in of flow lines or production risers to/from the manifold to the host facility.

2.4.3 Unitized template

The term "modular" can also be applied to the method of constructing the other components of a template system. For example, a multi well/manifold template can be described as being modular (even if the well-spacer template was run as a single piece, as the hinged design described above) if the manifold, pigging valve assembly, etc., are installed after the template. The alternative to this type of modularization is installation of a multi well/manifold template all-in-one-piece/unit. This type of template is often referred to as a unitized template, and a heavy-lift vessel is typically required to install it.

2.4.4 Well spacer/Tie-back template

A well spacer/tie-back template is a multi well template used as a drilling guide to predrilled wells before surface facilities installation. Often these types of wells are subsequently tied back to the surface facility during completion (Refer Figure 12). The wells can also be completed using subsea trees and individual production risers from each subsea tree, tied back to a floating or fixed host facility located above the template. Alternatively, a manifold may be subsequently landed on the template, thus effectively converting this system into a multi well manifold template, as described further below. If subsea trees are to be installed on the template, it should provide proper mechanical guidance for positioning of the trees and sufficient room for all installation and intervention operations.

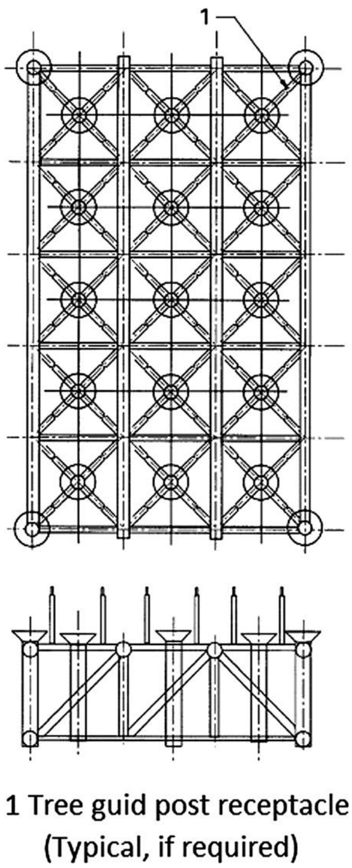

Figure 12: Well spacer/Tie-back template [15]

2.4.5 Riser support template

A riser support template is a simple template which supports a marine production riser or loading terminal, and also reacts to loads on the riser throughout its service life (Refer Figure 13). This type of template which may also include a pipeline connection capability can be integrated with other types of template, e.g. a manifold template or a multi well manifold template.

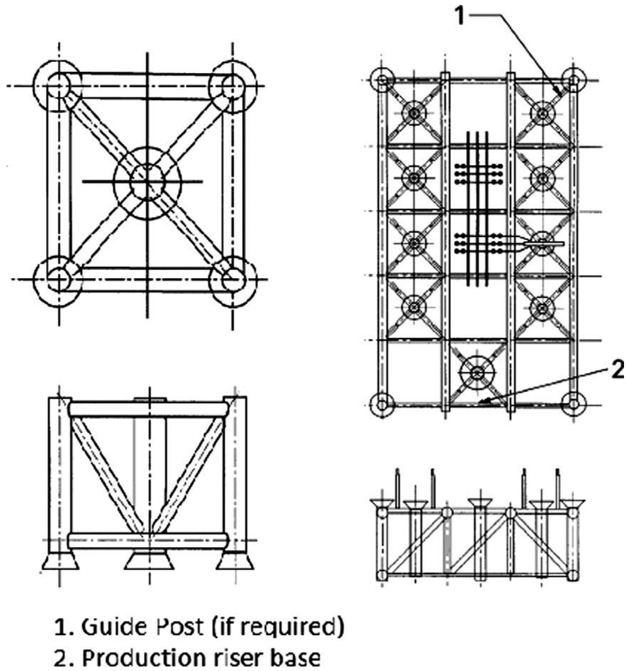

Figure 13: Riser support template [15]

2.4.6 Modular

The term “modular” can also be applied to the method of constructing the other components of a template system whereby the components may be installed as one unit or as modules assembled around a base structure. For example, a multi well/manifold template can be described as being modular (even if the well-spacer template was run as a single piece, as the hinged design described above) if the manifold, pigging valve assembly, etc., are installed after the template. The alternative to this type of modularization is installation of a multi well/manifold template all-in-one-piece/unit. This type of template is often referred to as a unitized template, and a heavy-lift vessel is typically required to install it.

2.5 Transportation and Installation vessels

Once the desired template has been fabricated, it is time to transfer the template to the field using vessels or barges and then installing the template with the guidance of a dive support vessel also known as remotely operated underwater vehicle (ROV). Selection of the proper transportation barge and the arrangement of the structures on the deck depend primarily on the following features:

- Dimensions, weight, and centre of gravity
- Distance and transportation route
- Schedule constraints
- Cost
- Ability to withstand bad weather

Vessel performance issues for and installation vessel include the following:

- Buoyancy: The vessel should be at buoyancy conditions such as upright position, trim, heel, and a combination of those conditions.
- Stability: The vessel return to its initial balanced position once the forces or moments applied on it removed.
- Insubmersibility: Vessel able to remain buoyant and stable once one space or multiple spaces of the vessel is flooded.
- Sea-keeping: Vessel can remain safe while navigating or operating at sea, even though it is exposed to the strong forces and moments created by wind, waves, and current.
- Manoeuvrability, speed, and resistance: Vessel capable to keep a constant navigation direction or change direction only according to the pilot's desire. Speed and resistance refers to the speed capability of the vessel at the rated power of the main engine.

2.5.1 Semi-submersible crane vessel

A semi-submersible crane vessel (SSCV) is a specialised marine vessel used in a number of specific offshore roles such as offshore drilling rigs, safety vessels, oil production platforms, and heavy lift cranes. Semi-submersible vessel is very stable for offshore construction because it consists of two lower hulls, three columns on each pontoon and an upper hull. During transit an SSCV will be de-ballasted to a draught where only part of the lower hull is submerged. During lifting operations, the vessel will be ballasted down. This way, the lower hull is well submerged reducing the effect of waves and swells. High stability is obtained by placing the columns far apart allowing lifting extremely high loads. Besides that, in the last few years SSCV have also been involved in decommission work.

Figure 14: SSCV Thialf during operation [16]

Example of a successfully built SSCV is the SSCV Thialf (Refer Figure 14) which has two cranes with a combined maximum lifting capacity of 14,200 metric tons, making it the largest crane vessel in the world. The hull consists of two pontoons with four columns each. Transit draught is about 12 metres. For lifting operations it will normally be ballasted down to 26.6 m. It is able to accommodate 736 people. Lightship weight is 72,484 tonnes [16].

2.5.2 Monohull vessel

A monohull vessel usually consists of a single hull and can perform installation work up to 400tonnes. Some monohull vessels are built flat bottom such as the Nordic vessel but this type of vessel will performs poorly in extreme sea environment due to its shape and dimension. Therefore this type of vessel normally operates at calm waters such as the Gulf of Mexico and also Asian waters.

Figure 15: Nordic monohull vessel [17]

One of the disadvantages of the monohull design is the requirement to use ballast for stability. The ballast can be made up of virtually anything that might weigh the vessel down and offset any wind or wave that may capsize the boat. The disadvantage is that unless the ballast is made up of a product that will float, the boat might sink if too much water intake. Some monohull designs actually have a dual hull design such as tankers which carry oil and liquid cargo. This design consists of a hull inside of a hull that allows a hollow space to exist between the two hulls which protect the ship from punctures if it should encounter an object, thus preventing dangerous and expensive leaks [17]. Figure 15 shows a Nordic monohull vessel.

2.5.3 Catamaran vessel

Figure 16: Svanen catamaran vessel [18]

Catamaran vessel consists of dual parallel hull with equal size therefore providing more stability compared to monohull vessel. The world's largest Catamaran vessel named Svanen is shown in Figure 16. A catamaran is geometry-stabilized, that is, it derives its stability from its wide beam, rather than having a ballasted keel like a monohull. The downside of being ballast-free and lighter than a monohull is having a very shallow draught. The two hulls designed to be much finer than a monohull's to reduce drag allowing faster speeds. In case one of the hulls damaged, there is still another one for buoyancy. A hull fracture on a monohull is a far more serious and dangerous compared to multihull [18].

2.5.4 Barges

Figure 17: Crane barge [19]

In 1949, J. Ray McDermott had the Derrick Barge Four built, a barge that was outfitted with a 150 tons revolving crane. The arrival of this type of vessel changed the direction of the offshore construction industry. Instead of constructing oil platforms in parts, jackets and decks could be built onshore as modules. For use in the shallow part of the Gulf of Mexico, the cradle of the offshore industry, these barges sufficed. A Crane Barge (Refer Figure 17) is a crane which can be towed or sometimes self propelled from place to place. This crane is usually mounted on a barge or pontoon and it is used to lift and move heavy objects. This crane as shown in Figure 8 is also referred to as a floating crane. Barges save cost in transportation since it is cheap to hire. Barges are also cheap to build because the design does not involve much equipment on board and the hull is built for both structural and ballasting purpose. As a cargo transporter, the barge represents large load capabilities to a relative low cost but the limitations are high. Barges also perform poorly in extreme wave conditions due to its characteristic of flat bottom hull [19].

2.5.5 Material/supply vessel

Figure 18: Platform Supply Vessel [20]

A Platform Supply Vessel (PSV) as shown in Figure 18 is a ship specially designed to supply goods and personnel to and from offshore oil platforms and other offshore structures. Other functions include returning cargo tanks for drilling mud, pulverized cement, diesel fuel, potable and non-potable water, and chemicals used in the drilling process to the shore. Fuel, water, and chemicals are almost always required by oil platforms. Certain other chemicals must be returned to shore for proper recycling or disposal, however, crude oil product from the rig is usually not a supply vessel cargo. Common and specialty tools are carried on the large decks of these vessels which are a combination of deck cargoes and bulk cargo in tanks below deck. Many ships are constructed to accomplish a particular job such as fire fighting capability, fire monitors for fighting platform fires, oil containment and recovery equipment to assist in the cleanup of a spill at sea. Other vessels are equipped with tools, chemicals and personnel to "work-over" existing oil wells for the purpose of increasing the wells' production [20].

2.5.6 Offshore support vessel

Figure 19: Offshore support vessel [20]

Offshore support vessels are special vessels that provide support for field drilling, construction, decommissioning, and abandonment. The support vessels normally include survey, standby, inspection, and monitoring. The following types of offshore support vessels may be utilized:

- ROV support vessel (RSV)
- Diving support vessel (DSV)
- Survey ship
- Offshore supply ship or field support vessel (FSV)

A RSV as shown in Figure 19 is a platform with specialized equipment and spaces to store, deploy, and support ROV for their subsea intervention. A DSV is a platform with specialized diving equipment, such as diver-to-surface communication system, submersible, on-site diving hyperbaric chamber, compression chamber, and so on for subsea interventions by professional divers. A survey ship is a platform with specialized instruments and laboratories for the study of the ocean physics, chemistry, geology, topography, aerography, and hydrology required for installation. A FSV is a multipurpose vessel that can provide transportation, supplies, and rescue and diving support [20].

2.6 Risk analysis

In recent years, many accidents have resulted in tens of thousands of lives lost, as well as environmental damages, and immeasurable economic lost. The goal of this industry is to provide diversified petroleum products in acceptable cost to the society but at the same time economically viable. The development of the industry are related to risk management since governments, the media and the general public are becoming more aware and in the same time are increasingly concerned about safety. Consequently, this leads to company's management forced to take critical decisions about the risks. The importance of risk analysis in the offshore industry is proven all over the world whereby Quantified Risk Analysis (QRA) is used as a fundamental tool for making decisions based on risk. There are four main objectives in using QRA [21]:

- Risk estimation in relation to risk acceptance criteria
- Determine design loads and conditions
- Understanding the cause of hazards and escalation methods
- Hazards ranking

Prior risk analysis, risk assessment is necessary to provide a basis for offshore operators to identify hazards (procedure known as HAZID) and ensure risks reduced to as low as reasonably practicable (ALARP) level. The primary purpose of hazard identification is to identify all possible hazards that may arise during normal operations carried out on the installation processes. The main objectives of the HAZID are:

- To identify hazards which may cause risk to personnel, operations or equipments
- To reduce the risk consequence to ALARP level
- To recommend the actions to control risk thus improving overall safety level of the project

There are also several other methods to achieve these objectives such as the use of checklists, Hazard and Operability studies (HAZOP), or Preliminary Hazard Analysis (PHA) but these approaches are not used during the course of QRA studies due to the lack of techniques which may identify human errors which may cause accidents.

2.7 Literature review summary

In conclusion from the literature survey it is understood that:

- Marginal field usually doesn’t require too many well slots as the reserve is limited.
- Adding extra well slots at later stage of development is not economically beneficial and also creates extra risk.
- It is better to design an optimum number of well slots and template at the beginning stage of field development than adding extra well slots later on.
- Research from previous case studies regarding the subsea technology has indicated the application of STS or ITS as preferable well template in marginal fields.
- There are several risk factors mainly weather condition which is present during transportation and installation of templates in South China Sea.
- The suitable vessel to be used to transport and install the template and weather condition needs consideration in order to save time and cost.
- Higher vessel’s heave period value means lower wave resonance energy effect.
- Heavier template operations suitable, safe and stable with vessel having higher heave period value and vice versa.

CHAPTER 3
METHODOLOGY

3.1 Project flowchart

This chapter describes the methods that will be followed through to achieve the objectives of the project. The overall project flowchart in order to achieve the project's objective is provided in Figure 20:

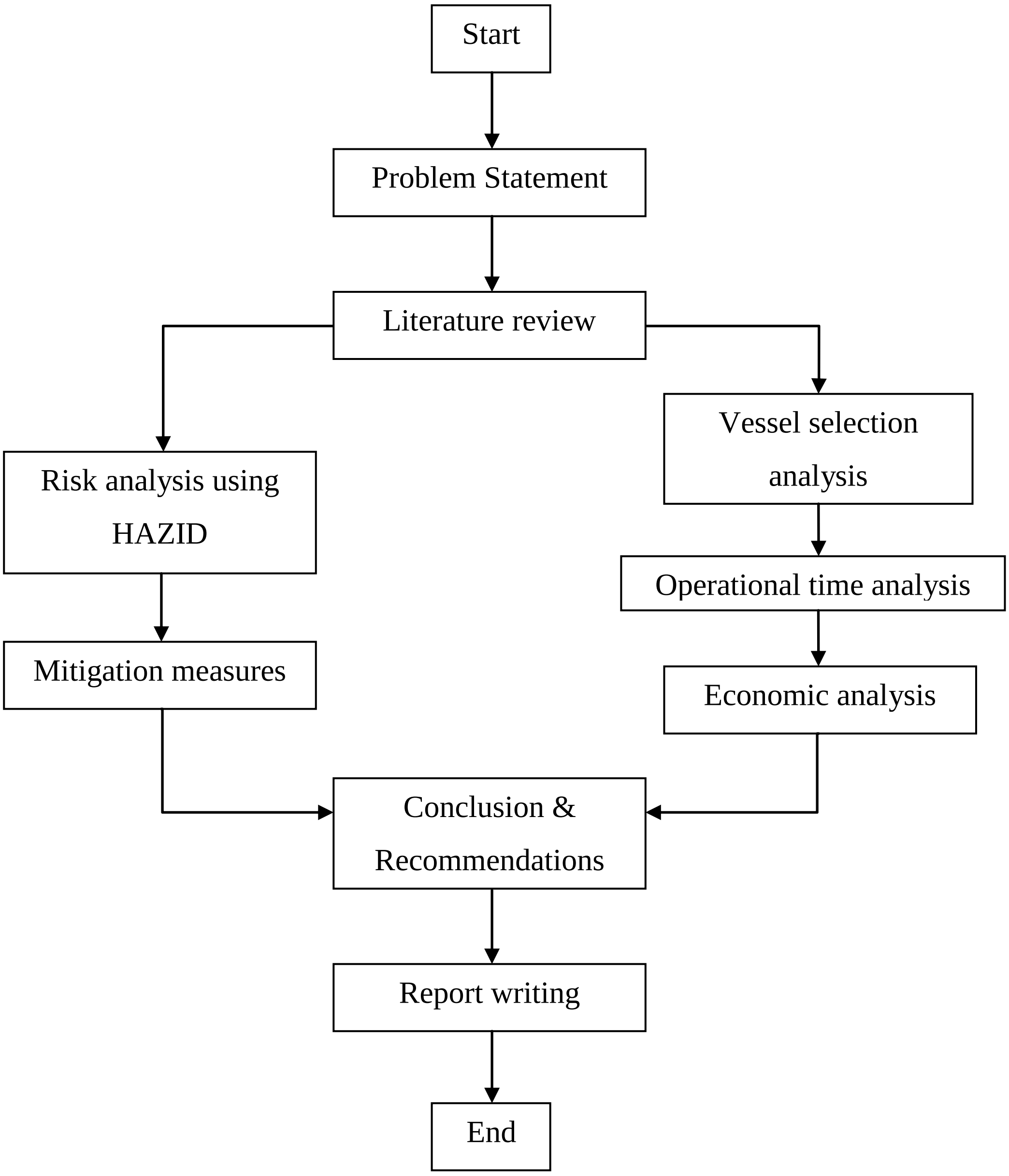

Figure 20: Project flowchart

3.2 Vessel selection analysis

The first analysis to be done in this project is the transportation vessel analysis to determine the most suitable and reliable vessel to be used to transport the templates to the Sepat marginal field. In order to select the most suitable vessel to install the template, heave response of each installation vessel needs to be calculated and compared. It is known that the lower this heave response, the worse the performance of the vessel in waves. The formulas to be used are listed.

The natural heave period formula by O. T. Gudmestad in 2011 [22] and also by Marr, Miller, and Schultz in 1997 [23]:

$$T_{heave} = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{m_{tv}+m_a}{A_W\times\rho\times g}} \qquad \text{Eq (3.1)}$$

The stiffness k is determined as the resistance against the vertical motion:

$$k = A_w \times \rho \times g \qquad \text{Eq (3.2)}$$

And,

$$A_w = l \times w \qquad \text{Eq (3.3)}$$

Whereby:
A_w = area at waterline (m²)
ρ = average seawater density (1025kg/m³)
g = gravity acceleration (9.81m/s²)

The true mass m takes account both total vessel mass m_{tv} as well as the added mass m_a generated by the moving vessel whereby:

$$m = m_{tv} + m_a \qquad \text{Eq (3.4)}$$

Firstly, the added mass m_a for the SSCV is done by assuming a prism shaped vessel base by Gary in 2013 [24] and [25]:

$$m_a^{sscv} = \rho \times C_A^{sscv} \times w^2 \times l \quad \text{Eq (3.5)}$$

Whereby:
C_A^{sscv} = added mass coefficient for SSCV
w = width (m)
l = length (m)

Similarly for Catamaran type vessel which has double prism shaped vessel base:

$$m_a^{ctr} = \rho \times C_A^{ctr} \times 2(w^2 \times l) \quad \text{Eq (3.6)}$$

Note* - C_A^{ctr} = added mass coefficient for Catamaran vessel

Meanwhile for Monohull vessel which have a rectangular shaped vessel base, the formula is slightly different given:

$$m_a^{mh} = \rho \times C_A^{mh} \times \tfrac{\pi}{4} \times w^2 \times l \quad \text{Eq (3.7)}$$

Note* - C_A^{mh} = added mass coefficient for Monohull vessel

The total vessel mass m_{tv} is inclusive of the template mass m_t and vessel mass m_v whereby:

$$m_{tv} = m_t + m_v \quad \text{Eq (3.8)}$$

3.3 Operational time analysis

The second analysis to be done is the template transportation and installation time analysis which determines the most optimum template to be installed at Sepat marginal field. The total operation time T_{total} (hours) required in order to successfully install the template is simply the template transfer period $T_{transfer}$ from the harbour to the field location added to the installation time $T_{installation}$ for each template. This can be show as given formula by Jean Masseron in 1990 [26]:

$$T_{total} = T_{transfer} + T_{installation} \qquad \text{Eq (3.9)}$$

The installation time $T_{installation}$ for each template is given in APPENDIX A meanwhile the total transfer time $T_{transfer}$ which is actually the two way transfer time from the harbor to Sepat field and back to the harbor can be calculated using the given formula:

$$T_{transfer} = (2 \times Distance) \div Vessel\,Velocity \qquad \text{Eq (3.10)}$$

3.4 Economic analysis

The third analysis to be conducted in this project is the economic analysis which determines the most cost beneficial template as well as the best operation method with and without including weather factor. This is done using formula [26]:

$$Cost_{total} = Daily\,rent \times T_{total} \qquad \text{Eq (3.11)}$$

And also using formula;

$$T_{wtotal} = T_{total} \times WOW\ factor \qquad \text{Eq (3.12)}$$

3.5 Risk analysis

HAZID is “the process of identifying hazards, which forms the essential first step of a risk assessment.Steps in identifying and consequently preventing risks and hazards:

1. To obtain a list of hazards for subsequent evaluation using other risk assessment techniques. This is sometimes known as “failure case selection”.
2. To perform a qualitative evaluation of the significance of the hazards and the measures for reducing the risks from them. This is sometimes known as “hazard assessment”.

3. To recommend actions that is significant in improving the overall safety level of the project.

The primary purpose for performing HAZID study in this project is to identify the hazards that will give the input for the template design and installation process.

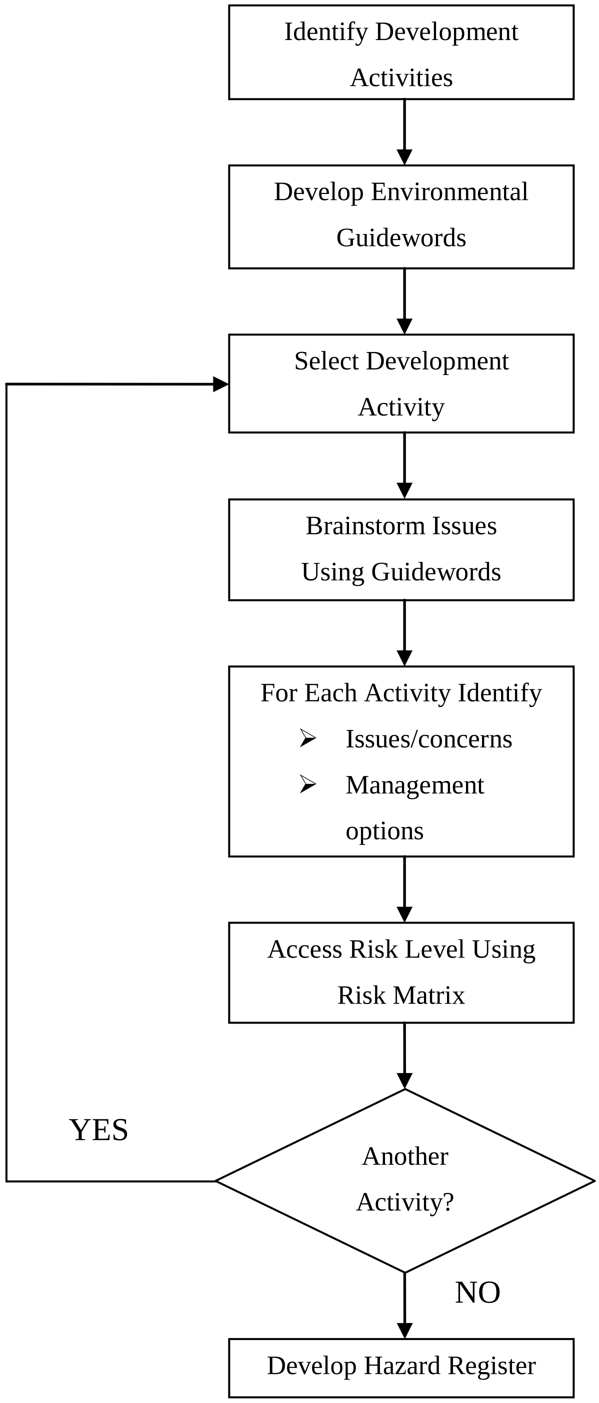

Figure 21: HAZID methodology [27]

As shown in Figure 21, HAZID is focusing on the following project phases:

- Design
- Transportation
- Commission
- Installation
- Operation

The identified hazards will be assessed and ranked according to the risk assessment matrix present in Table 1. Risk mitigations are then decided based on the hazard assessment designed by Germanischer Lloyd Industrial Services in 2008 [28].

Table 1: Risk assessment matrix [28]

Severity	Description	Probability				
		A	B	C	D	E
		Very likely	Likely	Possible	Unlikely	Very unlikely
1	Very high	1A	1B	1C	1D	1E
2	High	2A	2B	2C	2D	2E
3	Moderate	3A	3B	3C	3D	3E
4	Slight	4A	4B	4C	4D	4E
5	Negligible	5A	5B	5C	5D	5E

The three different colors indicate the three safety zones described as:

1) Green (Acceptable)
2) Yellow (ALARP with mitigation)
3) Red (Unacceptable)

Probability rating is further explained in Table 2:

Table 2: Probability rating [28]

A	Very likely	Incident occurring inevitable
B	Likely	Incident occurring uncertain, but additional factor may result in an incident
C	Possible	Incident could occur with additional factors but otherwise unlikely to occur
D	Unlikely	Incident resulting from the presence of a rare combination of factors
E	Very unlikely	Incident resulting from the presence of a freak combination of factors

Risk severity is further explained in Table 3:

Table 3: Risk severity [28]

1	Very high	Must not proceed unless change task or further measure control
2	High	Should not proceed
3	Moderate	Can only proceed with senior management authorization
4	Slight	Allowed to proceed by those trained and authorized to do so
5	Negligible	Allowable

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Vessel selection

4.1.1 Heave response calculation

In order to select the most suitable vessel to transport the template, heave response of each installation vessel needs to be calculated and compared. It is known that the lower this heave response, the worse the performance of the vessel in waves.
The important parameters of each vessel necessary to execute the heave period calculation are included in APPENDIX A.

The stiffness k for each vessel is calculated and computed in Table 4:

Table 4: Stiffness value for vessels

Vessel type	Area at waterline, A_w(m²)	Stiffness, k (N/m)
DB 101(SSCV)	5340	53695.04
Sapura 3000 (Monohull)	5715.4	57469.78
Rambiz 3000 (Catamaran)	3740	37606.64

Recall that true mass m takes account both total vessel mass m_{tv} as well as the added mass m_a generated by the moving vessel. Therefore the added mass m_a for each vessel is calculated and computed in Table 5:

Table 5: Added mass value

Vessel type	Added mass, m_a(tonnes)
DB 101(SSCV)	71921
Sapura 3000(Monohull)	132196
Rambiz 3000(Catamaran)	229396

The mass for each template and the mass for each vessel are referred from APPENDIX A. Therefore the total vessel mass m_{tv} for each vessel is calculated and computed in Table 6:

Table 6: Total vessel mass

Vessel type	Vessel mass, m_v (tonnes)	Total vessel mass, m_{tv} (tonnes)			
		STS-3 template	STS-4 template	ITS-3 template	ITS-4 template
DB 101 (SSCV)	52313	53213	53513	54113	54713
Sapura 3000 (Monohull)	32060	32960	33260	33860	34460
Rambiz 3000 (Catamaran)	7547	8447	8747	9347	9947

Finally the natural period of the heave, T_{heave} for each vessel is calculated and computed in Table 7:

Table 7: Heave period for vessels

Vessel type	Heave period, T_{heave} (seconds)				Averaged Heave period, T_{heave} (seconds)
	STS-3 template	STS-4 template	ITS-3 template	ITS-4 template	
DB 101(SSCV)	19.19	19.21	19.25	19.30	19.24
Sapura 3000(Monohull)	10.65	10.66	10.68	10.7	10.76
Rambiz 3000(Catamaran)	7.9	7.91	7.92	7.93	7.91

The results from Table 7 show the SSCV and monohull vessel being suitable because both can get in resonance with waves of South China Sea which is normally safe at a heave period value of above 10seconds [32]. SSCV is preferable for heavier template (ITS) structure because resonance energy effect is small in relation to its greater heave period value meanwhile monohull vessel sufficient for lighter template structure (STS). Catamaran vessel cannot be utilized due to very low natural period value causing unstable marine operation therefore excluded from further analysis in following sections. If there is desire to use Catamaran vessel, additional loads on deck is required to increase balance thus allowing stable operation in the South China Sea.

4.1.2 Operational time calculation

For this project, I've chosen two different type of template structure which are STS and ITS respectively. Both template structures manipulated factor is the template quantity, whereby each having three and four templates. Further details of these templates were included in APPENDIX B section of this report. The total time T_{total} (hours) required in order to successfully install the templates is simply the template's transfer period ($T_{transfer}$) from the harbour to the field location added to the installation time ($T_{installation}$) for each template. The total installation time $T_{installation}$ (days) for each template type is presented in Table 8:

Table 8: Template installation time [32]

Operation time	Template structure			
	STS-3template	STS-4template	ITS-3template	ITS-4template
$T_{installation}$ (days)	6	8	9	12

The transfer period is based on the time consumption to transfer the template from Kemaman Supply Base to Sepat field and back which is a distance of 130Km between both locations. This can be done since the distance between both mentioned locations is known and also the vessel's average speed can be referred from APPENDIX A. Assumption made prior calculating the transfer time is that vessel order has been done earlier and vessel is immediately available for use, thus no additional vessel waiting time is included in calculation. In reality it is crucial to plan and order the vessels earlier to avoid logistic predicaments. The two ways transfer time is presented in Table 9:

Table 9: Vessel transfer time

Vessel type	Vessel speed (knots)	Two way transfer time (Days)
DB 101(SSCV)	10	0.6
Sapura 3000 (Monohull)	8	0.8
ROV support vessel	14	0.4
Supply/Material barge	12	0.36

ROV support vessel and supply/material barge has been included in Table 9 because it is important equipment utilized during template installation operation. With adequate information of both transfer time and installation time, the calculated total time T_{total} is presented in Table 10:

Table 10: Vessel total operational time

Scenario	Transfer time (Days)				Installation time (Days)	Total operational time (Days)
	SSCV	Monohull	ROV support vessel	Supply/Material barge		
STS-3template	-	0.8	0.4	0.36	6	7.56
STS-4template	-	0.8	0.4	0.36	8	9.56
ITS-3template	0.6	-	0.4	0.36	9	10.36
ITS-4template	0.6	-	0.4	0.36	12	13.36

It is clearly presented in Table 10 that the transfer times for the vessels are different. This is due to the variation in vessel speed whereby the SSCV moves at a higher speed compared to the monohull vessel. The differences in transfer time for the vessels are indeed very small because the distance from the port to the Sepat field is relatively short, but there are cases of very large transfer time differences and vessel selection process is significant under these circumstances because of the effect on time is directly proportional to money. Results show that the operation times for the templates are different whereby ITS with four templates has the longest operational time of 13.36 days and STS with three templates has the shortest operational time of 7.56 days. This is due to the variation in vessel speed whereby the SSCV moves at a higher speed compared to the monohull vessel and also template installation time whereby ITS which is heavier and complicated consumes more time during installation.

4.2 Economic analysis

Reduced capital expenditures are a recurring theme going on right now across the oil and gas industry. It is believed that reducing capital expenditures will indeed boost profit. The purpose of this section is to provide a conceptual framework for understanding how costs and benefits might influence the return of the investments especially in a marginal field development project which has less hydrocarbon resources but higher risk. Usually, in order to maximize profit by reducing cost several methods can be fulfilled.

The well known cost reduction methods are:

- Early production execution time
- Accelerated facilities installation time
- Efficient utilization of available resources

Each type of vessel has its own pre-determined daily rental rate. However, the daily rental rate is influenced by various factors such as vessel demand, vessel specification, inflation rate, and also political relations. For this project the daily rent of the equipment is assumed to be at standard rate based on general survey and not influenced by inflation. The daily rental rates of vessels are presented in Table 11:

Table 11: Daily rental rate of vessels

Vessel type	Daily rent of vessels ($/Day)			
	STS-3template	STS-4template	ITS-3template	ITS-4template
DB 101(SSCV)	-	-	600,000	750,000
Sapura 3000 (Monohull)	250,000	400,000	-	-
ROV support vessel	100,000	100,000	100,000	100,000
Supply/Material barge	50,000	50,000	50,000	50,000

By obtaining daily rental rate for the vessels, total cost of each vessel can be determined. Total cost is defined as the cost for mobilization to field from harbor and cost during operation period. Total cost can be calculated by considering the total time for each type of vessel which has been determined in the previous section. Total cost for each vessels and each scenario is presented in Table 12:

Table 12: Total costing of each vessel

Scenario	Crane vessel	ROV support vessel	Supply/Material barge	Total cost, $M
STS-3template	1890000	756000	378000	3.1
STS-4template	3824000	956000	478000	5.3
ITS-3template	6216000	1036000	518000	7.8
ITS-4template	10020000	1336000	668000	12.1

The total cost calculated in Table 12 is based on direct calculation which is not affected by external factors. Usually, external factors such as waiting on weather (WOW) and waiting on equipment presence is unavoidable. Waiting on equipment cannot be determined precisely for this project because this value depends on the efficiency during real time operations. Therefore, it is assumed for this project to be perfectly effective whereby there is no delay in equipment transferring meaning that all vessels arrive simultaneously on time. The WOW factor for Sepat field operation is assumed to be 1.25(25%) due to the occurrence of Northeast Monsoon at this region from November to March annually which is suggesting a non-safe period of three months annually. By obtaining the total time with WOW factor, total cost can be recalculated to give revised value. Total costs for operations with WOW factor are presented in Table 13:

Table 13: Total cost with WOW factor

Scenario	Total days with WOW, T_{wtotal}	Total cost with WOW,$M
STS-3template	9.5	3.8
STS-4template	12	6.6
ITS-3template	13	9.75
ITS-4template	17	15.3

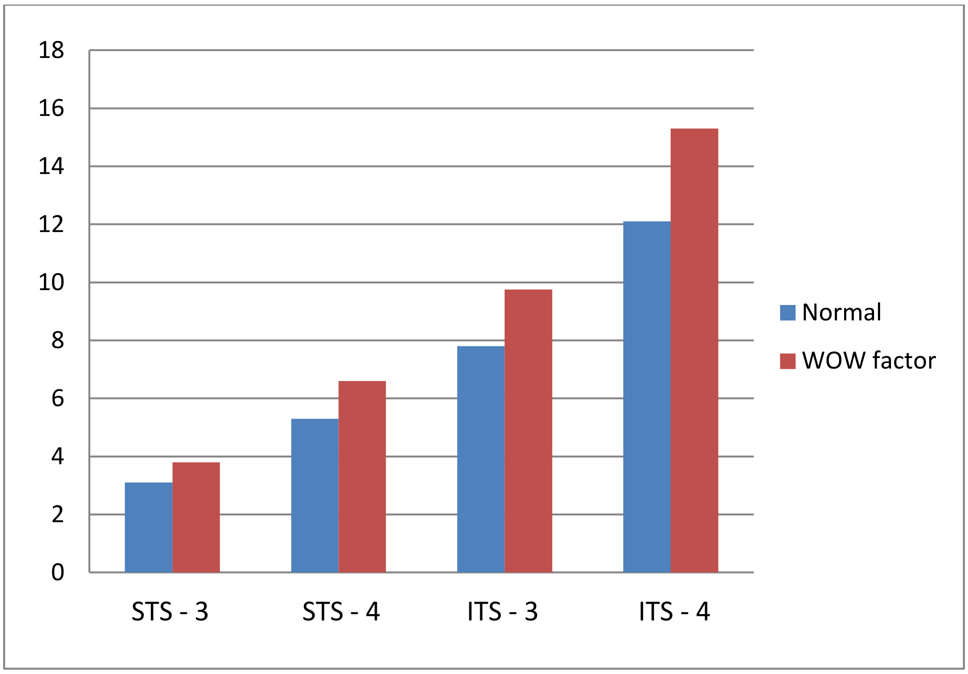

Figure 22: Total cost comparison chart.

Figure 22 presents the comparison between total operation cost of operations under normal weather conditions and with WOW factor affecting the operation. The WOW factor has increased the operational cost of the templates. This is because of more days without operation waiting for the bad weather to recede. Another cause of cost difference is largely due to the type of vessel deployed for operation whereby SSCV daily rental rate is fairly higher than of monohull. Cost analysis also shows that STS is preferable than ITS due to lower total cost. This is because of the simplicity and lighter mass of STS consuming shorter operation time thus lower total cost. The comparison within both types of STS shows obvious findings whereby STS with three templates is slightly cheaper to build and faster to install compared to STS with four templates.

4.3 Risk analysis

It is known that marine operations conducted in the South China Sea can be challenging due to risk and hazards present. Those known risks and hazards are listed by Jan Erik Vinnem in 1998 [10]:

1. Weather conditions (e.g. Typhoon, Monsoon wind, Strong wave energy, Unpredictable weather)
2. Marine operational failures (e.g. Ballast system failure, Grounding, Foundering, Capsizing, Loss of buoyancy, Anchor system or towline failure)
3. Dropped loads
4. Vessel collision/impact (e.g. support vessel, dynamic vessel, static vessel)
5. Insufficient fuel
6. Wire damage
7. Vessel delay
8. Loss of marine/utility systems (e.g. propulsion, engine breakdown, hydraulics or navigation failure)
9. Personnel injury/accident
10. Poor sea fastening

The identified hazards will be ranked, analyzed and classified according to the risk matrix. In the industry, this process is known as Job Risk Assessment (JRA) to ensure risk controls can be prepared before the work begins. A risk matrix will allow us to quantify the probability and severity of the hazards and risk of the operational activity. The product of both probability and severity indicates the risk level. The next step is to reduce the risk level to an ALARP level but introducing mitigation measures. In this project, there are two different types of template operations to be considered for risk assessment each possessing different type of hazards and mitigation measures. The risk rating certainly will be higher on ITS operations compared to STS operations due to more complicated and heavier operations of larger templates. This will be the basis for the risk assessment activity. The JRA for STS operations are presented in Table 14.

Table 14: Job risk assessment for STS operations

Initial assessment						Final mitigated assessment	
Item no	Specific activity	Hazards identified	Severity	Probability	Initial risk*	Risk-reducing measures	Final risk
1	Transportation Installation	Bad weather. Strong wind, wave, current	2	B	2B	Frequent weather forecast; Updates from weather station	2C
2	Transportation	Marine operational failures	1	C	1C	Double hull; Detail check of vessel response in wave/heave period	1D
3	Installation	Dropped loads	1	D	1D	Improve installation safety; Frequent maintenance	1E
4	Transportation	Vessel collision/impact	1	D	1D	Improve navigation safety	1E
5	Transportation	Insufficient fuel	5	D	5D	Standby fuel on board	5E
6	Installation	Wire damage/snapping	2	B	2B	Thorough load calculation; Frequent maintenance	2C
7	Transportation	Vessel delay	3	C	3C	Early pre-planning; Logistic studies	3D
8	Transportation	Loss of marine/utility systems	1	C	1C	Qualified personnel; Frequent maintenance	1D
9	Installation	Personnel injury/accident	1	D	1D	Personnel safety enhancement; Medical facilities available	1E
10	Transportation Installation	Poor sea fastening	2	C	2C	Double check on work; Personnel training	2D

*Risk = Probability x Severity

The final risks of STS operations after mitigations are recorded in a risk matrix as shown in Table 15.

Table 15: Risk matrix for STS operations after risk mitigation

Severity	Description	Probability				
		A	B	C	D	E
		Very likely	Likely	Possible	Unlikely	Very unlikely
1	Very high				2,8	3,4,9
2	High			1,6	10	
3	Moderate				7	
4	Slight					
5	Negligible					5

The JRA for ITS operations are presented in Table 16.

Table 16: Job risk assessment for ITS operations

Initial assessment						Final mitigated assessment	
Item no	Specific activity	Hazards identified	Severity	Probability	Initial risk*	Risk-reducing measures	Final risk
1	Transportation Installation	Bad weather. Strong wind, wave, current	2	B	2B	Frequent weather forecast; Updates from weather station	2C
2	Transportation	Marine operational failures	1	B	1B	Double hull; Detail check of vessel response in wave/heave period	1C
3	Installation	Dropped loads	1	A	1A	Improve installation safety; Frequent maintenance	1B
4	Transportation	Vessel collision/impact	1	C	1C	Improve navigation safety	1D
5	Transportation	Insufficient fuel	5	D	5D	Standby fuel on board	5E
6	Installation	Wire damage/snapping	2	A	2A	Thorough load calculation; Frequent maintenance	2B
7	Transportation	Vessel delay	3	C	3C	Early pre-planning; Logistic studies	3D
8	Transportation	Loss of marine/utility systems	1	C	1C	Qualified personnel; Frequent maintenance	1D
9	Installation	Personnel injury/accident	1	C	1C	Personnel safety enhancement; Medical facilities available	1D
10	Transportation Installation	Poor sea fastening	2	B	2B	Double check on work; Personnel training	2C

The final risks of STS operations after mitigations are recorded in a risk matrix as shown in Table 17.

Table 17: Risk matrix for ITS operations after risk mitigation

Severity	Description	Probability				
		A	B	C	D	E
		Very likely	Likely	Possible	Unlikely	Very unlikely
1	Very high		3	2,	4,8,9	
2	High		6	1,10		
3	Moderate				7	
4	Slight					
5	Negligible					5

Each type of template structure has its own installation procedures and risks. The risk rating increases due to more complex and heavy lifting operations of larger templates.

From Table 15, we know that identified hazards were located within acceptable/ neglible zones after mitigating measures. This shows that STS operations are common, safe, reliable and easier to execute.

From Table 17, it is proven that the most hazardous operations is the ITS operations due to heavyweight issue and complicated installation nature in the South China Sea. Four out of ten hazards fall inside the red zone indicating high risk operation. Hazards such as dropped loads or wire snapping are very dangerous and can affect operational cost and time and most importantly life of personnel on board.

We have to consider all processes and all assets involved to establish a more accurate risk assessment matrix for each scenario. More brainstorming required to identify risk mitigating measures in order to suppress the risks involved.
From the safety point of view, the STS preferable than ITS for its lower risk and easy operation handling.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

In this thesis an analysis of the selection of template structure and transportation vessel was presented. Analysis done consists of basic calculations, cost comparison, and risk assessment which all of these analyses has been done under limited information. Firstly, analysis to determine the most suitable vessel to be use for template operations in the South China Sea was conducted. From analysis, it is believed that SSCV and monohull vessel are suitable to be deployed in the South China Sea because of having high heave period value with value of 19.24 seconds and 10.67 seconds respectively. Catamaran vessel cannot be utilized due to very low natural period value with a value of 7.91 seconds. Next, vessel operational time calculation can be done. Results show that the operation times for the templates are different whereby ITS with four templates has the longest operational time of 13.36 days and STS with three templates has the shortest operational time of 7.56 days. Since time has been determined, cost relevant to time can also be determined. Results show total cost is lowest for STS consisting three templates with a cost of $3.1 Million and highest for ITS consisting four templates with a cost of $12.1 Million which is almost four folds of the lowest cost mentioned making STS preferable. The total cost with WOW factor included for STS consisting three templates are $3.8 Million meanwhile for ITS consisting four templates with a revised cost of $15.3 Million still retaining STS as preferable selection. From risk analysis, we can conclude that the risk rating higher for ITS operations compared to STS operations due to more complicated and heavier operations of larger ITS templates in the South China Sea. From the safety point of view, the STS preferable than ITS for its lower risk and easy operation handling. Based on all analysis done in this project, it is now very clear that STS is a better solution for template selection to be installed at marginal fields located in South China Sea meanwhile both SSCV and monohull vessel are compatible for marine operations in the South China Sea. The objectives of this project were achieved.

5.2 Recommendation

It is highly recommended that

- Future works must include more detailed template and crane vessel data for more detailed analysis.
- Other relevant simulations in the field of drilling or reservoir are necessary to determine the exact amount well slot quantity and type of template to use.
- More sea condition parameters such as wind speeds, wave height or sea temperature is significant in providing better solutions for vessel selection.
- Additional cost analysis can be done for developed field by including operational costs (OPEX) and net present value (NPV).
- Risk analysis can be improved by obtaining more historical data and past real life experiences.

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APPENDIX A

Table A-1: Vessel specifications

Vessel	Vessel mass (tonnes)	Length (m)	Width (m)	Maximum draft(m)	Lift capability (tonnes)	Added mass coefficient, C_A	Vessel speed
DB 101(SSCV)	52313	146.3	36.5	23.5	3175	0.36	10
Sapura 3000 (Monohull)	32060	151.2	37.8	6.5	3000	0.76	8
Rambiz 3000 (Catamaran)	7547	85	44	12.5	3300	0.68	10

Table A-2: Template specifications (Subsea7, 2011) [32]

Template Structure	Total Mass(tonnes)	Installation time(days)
STS-3template	900	6
STS-4template	1200	8
ITS-3template	1800	9
ITS-4template	2400	12

APPENDIX B

Table B-1: Excel calculation sheet

Sepat field	
Distance	130Km

Heave period calculation

Vessel	Vessel mass (tonnes)	Length (m)	Width (m)	Maximum draft(m)	Lift capability(tonnes)	Added mass coefficient	Area at waterline (m^2)	Stiffness	Added mass(Kg)	Added mass (tonnes)	Total vessel mass	Heave period (Sec)
DB 101(SSCV)	52313	146.3	36.5	23.5	3175	0.36	5340	53695.035	71,921,117	71921.1166	53888	19.2377893
Sapura 3000(Mono hull)	32060	151.2	37.8	6.5	3000	0.76	5715.4	57469.77585	132,196,220	132196.22	33635	10.6745499
Rambiz 3000(Catamaran)	7547	85	44	12.5	3300	0.68	3740	37606.635	229,396,640	229396.64	9122	7.91288958

Economic analysis

	SSCV	Monohull	ROV support vessel	Supply/Material barge	Install (days)	Total op days	Crane vessel	ROV support vessel	Supply/Material barge	Total cost, $M	Total cost WOW, $M
STS-3template	-	0.8	0.4	0.36	6	7.56	1890000	756000	378000	3.1	3.8
STS-4template	-	0.8	0.4	0.36	8	9.56	3824000	956000	478000	5.3	6.6
ITS-3template	0.6	-	0.4	0.36	9	10.36	6216000	1036000	518000	7.8	9.75
ITS-4template	0.6	-	0.4	0.36	12	13.36	10020000	1336000	668000	12.1	15.3

Vessel type	Daily rent of equipment ($/Day)			
	STS-3template	STS-4template	ITS-3template	ITS-4template
DB 101(SSCV)	-	-	600,000	750,000
Sapura 3000(Mono hull)	250,000	400,000	-	-
ROV support vessel	100,000	100,000	100,000	100,000
Supply/Material barge	50,000	50,000	50,000	50,000

Vessel Transfer time

Vessel type	Vessel speed	One way transfer	Two way transfer
DB 101(SSCV)	10	0.3	0.6
Sapura 3000(Mono hull)	8	0.4	0.9
ROV support vessel	14	0.2	0.4
Supply/Material barge	12	0.18	0.36